Development Of Crash-Survival Design In Personal, Executive and Agricultural Aircraft

By

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FOREWORD

This report discusses features of five aircraft in which basic structures and installations are designed to decrease exposure to injuries in accidents. In most cases a major increase of crashworthiness and greater safety has been achieved with little or no penalty in weight, cost or performance.

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Crash Injury Research is indebted to the following individuals and organizations, whose assistance in providing technical data for this report is acknowledged with appreciation: Mr. Fred E. Weick, Director of the Personal Aircraft Research Center, A. & M. College of Texas; Dr. O. C. Koppen, President and Dr. L. L. Bollinger, Chairman of the Helio Aircraft Corporation; Mr. T. A. Wells, Vice President and Chief Engineer of Beech Aircraft Corporation and Mr. Herb Rawdon, Consulting Engineer to Beech; Mr. Allen H. Meyers, President and Chief Engineer of Meyers Aircraft Company.

INTRODUCTION

In many accidents the forward sections of airplanes are broken up and destroyed in crashes which do not cause great damage to other parts of the structure. In early pusher-type planes, the pilots sat ahead of the wing and engine in areas which normally were first to be crushed and broken; often they were injured or killed in crack-ups which would have caused little injury if the pilot had been further back in the structure.

Later, in tractor types, it soon was realized that collapse of the nose sections pushed the engine back into the front cockpit, causing great danger in this area. Pilots recognized that the rear seat in tandem trainers was safer, and even in World War I the front cockpit often was referred to as the "meat-box".

Thus, from the earliest days of flying, it was generally understood that danger of injury - which is the foremost danger in flying - was dependent to a large extent on the configuration of the plane, the position of the engine and gas tank, the location of the pilot and the strength of cockpit or cabin structures.

Looking back on the history of flight, it is interesting to note that protection of airmen by aircraft structures usually occurred without deliberate engineering efforts to provide safety in accidents. Also, except in a few early military planes, no shoulder harness was provided and safety belts would not withstand the force of severe but survivable crashes. Therefore, when pilots walked away from serious accidents, this fortuitous result usually could be classified - with some justification - as miraculous!

In 1942 the Crash Injury Research project was established at Cornell University Medical College to systematically study the effectiveness of safety belt installations and typical causes of injury in severe lightplane accidents.

One of the first steps in this study was to find whether safety belts caused abdominal or spinal injuries and to analyze the comparative seriousness of injury sustained in the front seats and rear seats of small, tandem type planes. Analysis of 30 crashes in which both seats were occupied showed that the safety belts rarely caused injury, and that an astonishing degree of protection for the 30 occupants of the rear seats was provided by basic fuselage structures. The results of this study were issued, in 1943*, to all manufacturers of small planes.

* NATIONAL RESEARCH COUNCIL, COMMITTEE ON AVIATION MEDICINE, REPORT # 230, 11/17/43.

Further accumulation of data permitted a comparative study of injury causes in side-by-side as well as tandem type lightplanes. The results of this study - with a detailed breakdown of the relative frequency of head injuries, and a comparative study of the severity of injuries in comparable types of planes - was released by CIR in 1945.*

In brief, these reports showed that the ability of the human body to withstand crash force had been grossly underrated, and that pilots and passengers often sustained critical or fatal injuries:

(1) because they were seated in forward sections of the aircraft which were crushed and destroyed during the absorption of energy in the crash, or

(2) because they were thrown forcibly against dangerous objects, such as rigid steel seat-backs, sharp or solid instrument panels, and dangerous control wheels, which "pinpointed" forces on vital areas of the head and/or body.

In many of the survivable accidents studied, in which the cockpit and cabin structures remained substantially intact, the critically or fatally injured victims sustained nothing more than a single wound of the head or chest.

In addition, CIR accident-injury data indicated that slight differences in the design of two rather comparable basic fuselage structures could produce totally different degrees of danger from cabin collapse in seemingly identical crashes. Thus, identical "incidents" resulted in survivable accidents in those cases wherein cabin structures remained relatively intact; similar incidents in other, more fragile types of aircraft led to fatal and non-survivable crashes because cockpit and cabin structures failed.

During World War II, the author worked closely with engineers in the mock-up and development of three small planes (the Bendix, Fairchild and Waco) in which crashworthiness was featured in the design and engineering of basic structures. But, because of the limited nature of the post-war market for small planes, none of these planes were produced in volume and marketed. However, the Globe-Swift and Ercoupe - which included notable degrees of crashworthy design - were produced and repeatedly demonstrated their protective features.

It is noteworthy that efforts during the '40's to offset the danger of crash-injuries in civilian planes were limited to details such as stronger center sections and cabin structures, "softer" instrument panels, padded and pivoted seat-backs and safety engineering of seat belt and control wheel installations. Only in a few cases was the passenger compartment "moved back" in the plane - and, in no case was shoulder harness provided.

* NATIONAL RESEARCH COUNCIL. COMMITTEE ON AVIATION MEDICINE. REPORT # 440. 7/9/45.

In 1946, the findings and recommendations of Crash Injury Research were presented* at the Annual Meeting of the Institute of Aeronautical Sciences and, since that date, there has been a steadily increasing use of protective design to increase safety in accidents.

During 1948 and 1949, the author sat in at preliminary design discussions and mock-up conferences concerning three planes which were to embody radically new crashworthy features. They were:

(1) The CAA Texas A. & M. CROPDUSTER;

(2) The HELIOPLANE;

(3) The Beech TWIN BONANZA.

These planes incorporated most of the design details recommended by Cornell's Crash Injury Research which were summarized and released to Aviation Week for its article titled "Crash Safety Can Be Engineered". A reprint of this article from the March 13, 1950 issue of Aviation Week is seen in the *APPENDIX* of this report. Most of the features summarized in this article also are included in the Meyers 145.

Three *additional* aircraft now in design and/or early flight test stages embody major improvements for providing greater safety in accidents. They are: the Twin Cessna; the Meyers 4-place: the Mooney 4-place.

The Twin Cessna 5-place executive plane features, among other things, wing tip tanks to lessen the danger of post-crash fires.

A representative of Crash Injury Research is acting as consultant in the development of the Meyers 4-place and Mooney 4-place airplanes; design details concerning crashworthiness in these new planes will be the subject of a future CIR report on Developments in Crashworthiness.

* * * * * * *

During this period of development in small aircraft, manufacturers of large aircraft began applying concepts of protective design to airline seats. A marked "delethalization" of seat-backs was achieved in engineering passenger seats for the Convair 240 and Douglas DC-6 airliners by:

(1) the utilization of perforated ductile metals in seat-back structures;

(2) the development of recline mechanisms which would permit seat-backs to pivot forward in accidents;

(3) the padding of seat-backs;

(4) the development of attachments to floor structure in proportion to the increased holding capacity of safety belts.

These developments will be the subject of a future CIR report.

* DE HAVEN. "CRASH RESEARCH FROM THE POINT OF VIEW OF CABIN DESIGN", AERONAUTICAL ENGINEERING REVIEW. VOL. 5. #5. JANUARY. 1946.

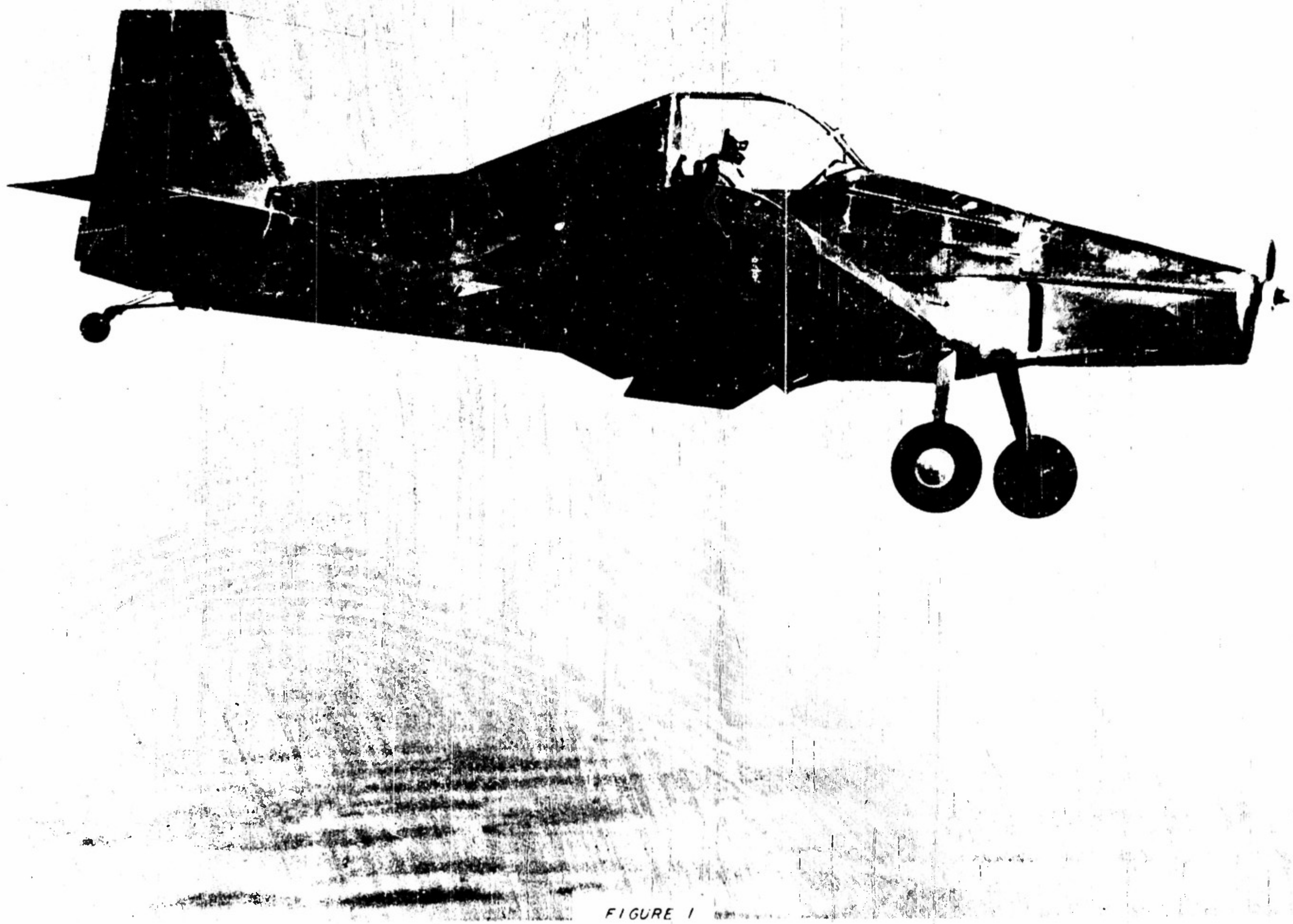

FIGURE 1

CAA-TEXAS A. & M.'s AGRICULTURAL AIRPLANE

This utility airplane (designated the AG-1) was developed expressly for agricultural use - dusting, spraying and seeding. Incorporated in its design is a 40g cockpit structure - along with excellent short field performance, a payload capacity of 1,000 pounds and excellent visibility.

In order to provide crash protection, it is desirable to locate the pilot as far aft as possible, with a large amount of energy absorbing structure ahead of him. It is also essential that duster pilots have exceptional 360° visibility. Combining these two requirements resulted in placement of the cockpit near the center of the fuselage in an elevated position, and above the rear portion of the wing. The pilot's seat is approximately 13 feet from the nose of the plane and the cockpit is behind all disposable loads.

To further insure pilot protection, a 40g seat - with military safety belt and integral two-strap shoulder harness with an inertia lock - is standard equipment. The spring-loaded inertia reel keeps the harness snugly on the pilot's shoulder but permits complete freedom of movement within the large cockpit during normal flight. Automatic locking of the reel under 3g loads is designed to prevent the pilot from striking the instrument panel, or any forward cockpit structure in a crash at normal operating speeds.

A high, head-rest structure is immediately behind the open cockpit; tubular guard rails extending from the turnover structure are designed to deflect wires and branches over the pilot's head.

The fuselage structure forming the cockpit area is designed to remain intact in a head-on collision at normal operation flight speeds of approximately 75 mph; the structural integrity of the 40g cockpit area makes this section a unit by itself, *independent* of the structure ahead of the cockpit.

The hopper-fuselage area - in front of the cockpit - while having the same strength as that of the cockpit, is considerably stronger than the "firewall" area immediately ahead. (See Fig. 1) However, the 40g strength of hopper depends on the firewall and adjacent structure remaining structurally intact; after their failure, the hopper structure can then only withstand a 25g load.

Thus - in a "head-on" crash, the initial impact is partially absorbed by the engine and its 15g mount; the remaining crash energy is transferred to the firewall structure just ahead of the hopper. After hopper failure - at 25g - the cockpit area can collapse only if the remaining deceleration is in excess of 40 g. However, by the time the nose section and the hopper structure collapse, it can be expected that the remaining energy will not be great and cockpit structures will provide a "40g island of safety" for the pilot.

FIGURE 2: BEECHCRAFT BONANZA

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BEECH BONANZA

The Beechcraft Bonanza, a single engine, 4 place executive-personal type airplane, weighs 2,700 pounds (gross) and cruises at a reported speed of 175 mph at 8,000 feet. Landing speed is approximately 55 mph. Minimum safe slow-flight speed, with landing gear extended and partial power, is from 55 to 65 mph, depending on load, turbulence, air density and piloting technique.

Various design items in the Beechcraft Bonanza (Models C and D-35) lessen chances of injury in moderate G, low speed accidents (60 to 80 mph). As described in a Beech Aircraft Corporation release, a number of the safety design features of the Bonanza correspond to Crash Injury Research recommendations outlined in CIR's summary published in Aviation Week, 3/13/1950 issue, *(Appendix)* "Crash Safety Can Be Engineered".

The Beech release is quoted as follows:

A. "The BEECHCRAFT Bonanza's long nose section provides gradual impact deceleration.

B. "The Bonanza's wing design provides crash shock absorption in addition to its rugged design which has been tested to over 8.4g's which is 47 percent above government required safety margins.

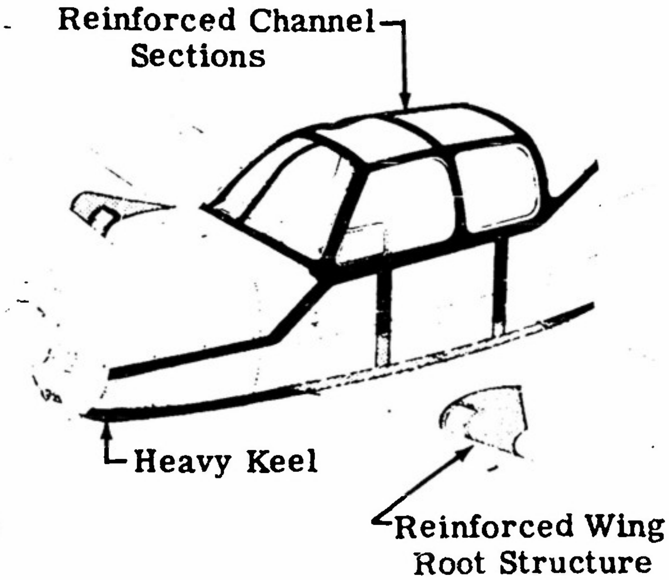


FIGURE 3

C. "The Bonanza's fuselage has a reinforced keel section providing occupant protection against crashes and lessening crash damage.

D. "The Bonanza's reinforced cockpit provides a strong crash-resistant passenger compartment or structurally-reinforced capsule for maximum occupant protection.

E. "The Bonanza instrument panel is installed with shearable shock mounts on the basic instrument panel with a thin gauge soft metal head shield to lessen the possibilities of passenger injuries in event of crash landing. (See Fig. 4)

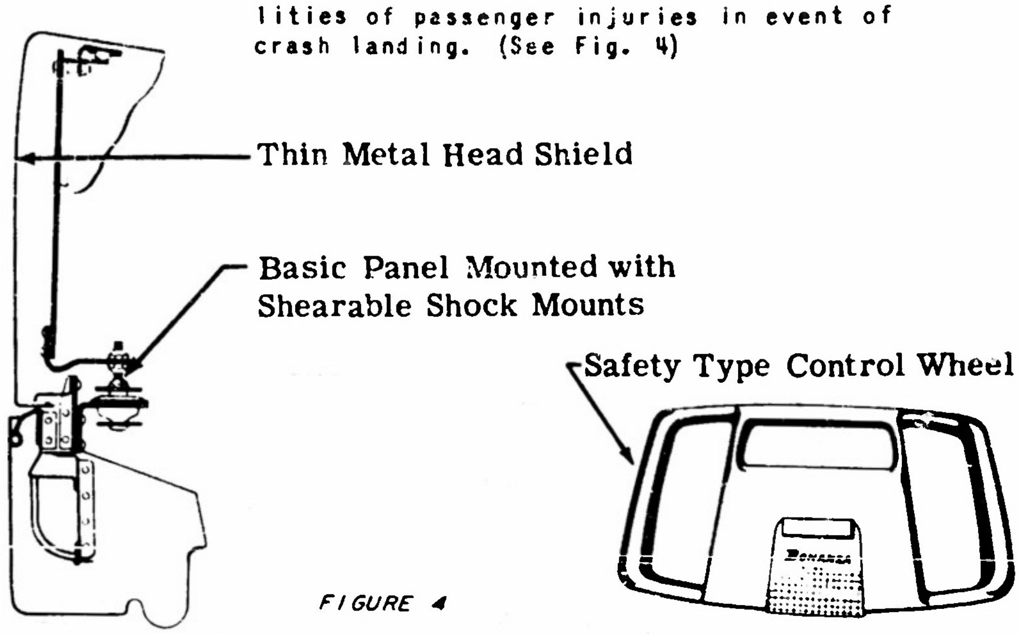
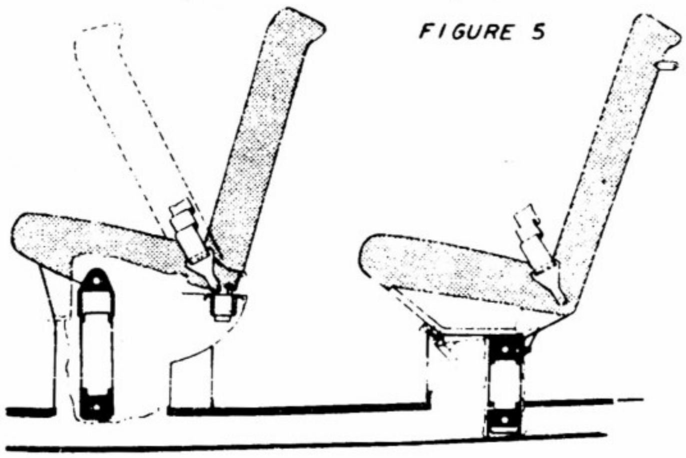


FIGURE 4

F. "The new Bonanza is equipped with a body supporting safety-type control wheel to reduce chest and lung injuries in event of crash landing.

FIGURE 5



Seats Mounted on Basic Structure

G. "The Bonanza seats and safety belts are securely mounted to the basic spar truss with the front seat-backs hinged to swing forward out of head range of occupants in the rear seat to provide a maximum of passenger protection."

In addition, as a result of Crash Injury Research data on the dangerousness and frequency of head injury in survivable aircraft accidents, as well as other studies, the Beech Aircraft Corporation developed a combination safety belt and shoulder harness which is available as optional equipment (See Fig. 6). Reportedly, the harness has been tested satisfactorily to about 20g.

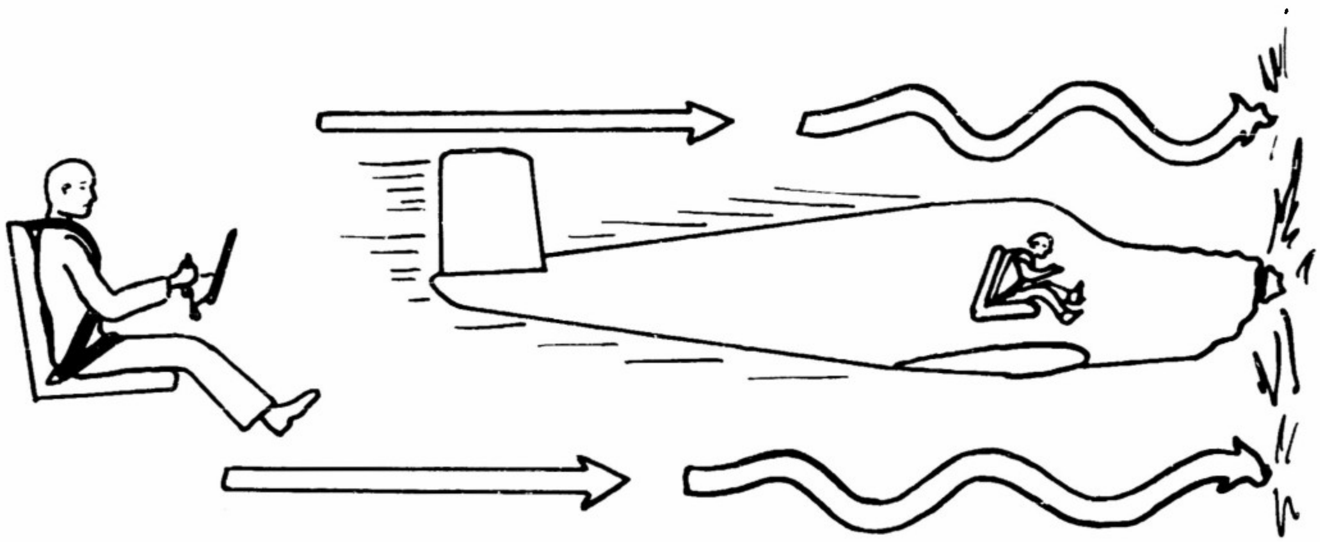


FIGURE 6

A Beechcraft release says:

"Many auto and airplane accidents occurring at decelerations as low as 2 or 3g's are fatal when the body is not restrained against hitting the interior parts of the vehicle or from flying out through a suddenly opened door. While no definite top limit has been established, survival of decelerations up to more than 25g's is considered possible with proper body restraint."

"The BEECHCRAFT safety harness marks a milestone in the progress of the new science of saving lives by preventive engineering. Its design is of such a nature that it is easy to use and is inconspicuous in appearance. This modern safety harness restrains the entire body in a sudden deceleration. It is standard equipment on the BEECHCRAFT Bonanza and Twin-Bonanza."

FIGURE 7: BEECH TWIN BONANZA

TWIN-BONANZA

The twin engine 6-place Beech Twin-Bonanza was designed to embody the structural ruggedness of a military trainer in combination with high performance. A cruising speed in excess of 180 mph at 10,000 feet, is claimed with 1,650 feet per minute rate of climb, a stall-speed of approximately 60 mph, and a safe minimum slow-flight speed with partial power of about 75 mph; the wing loading (at maximum gross load of 5,500 pounds) is in the order of 20 pounds/sq.ft.

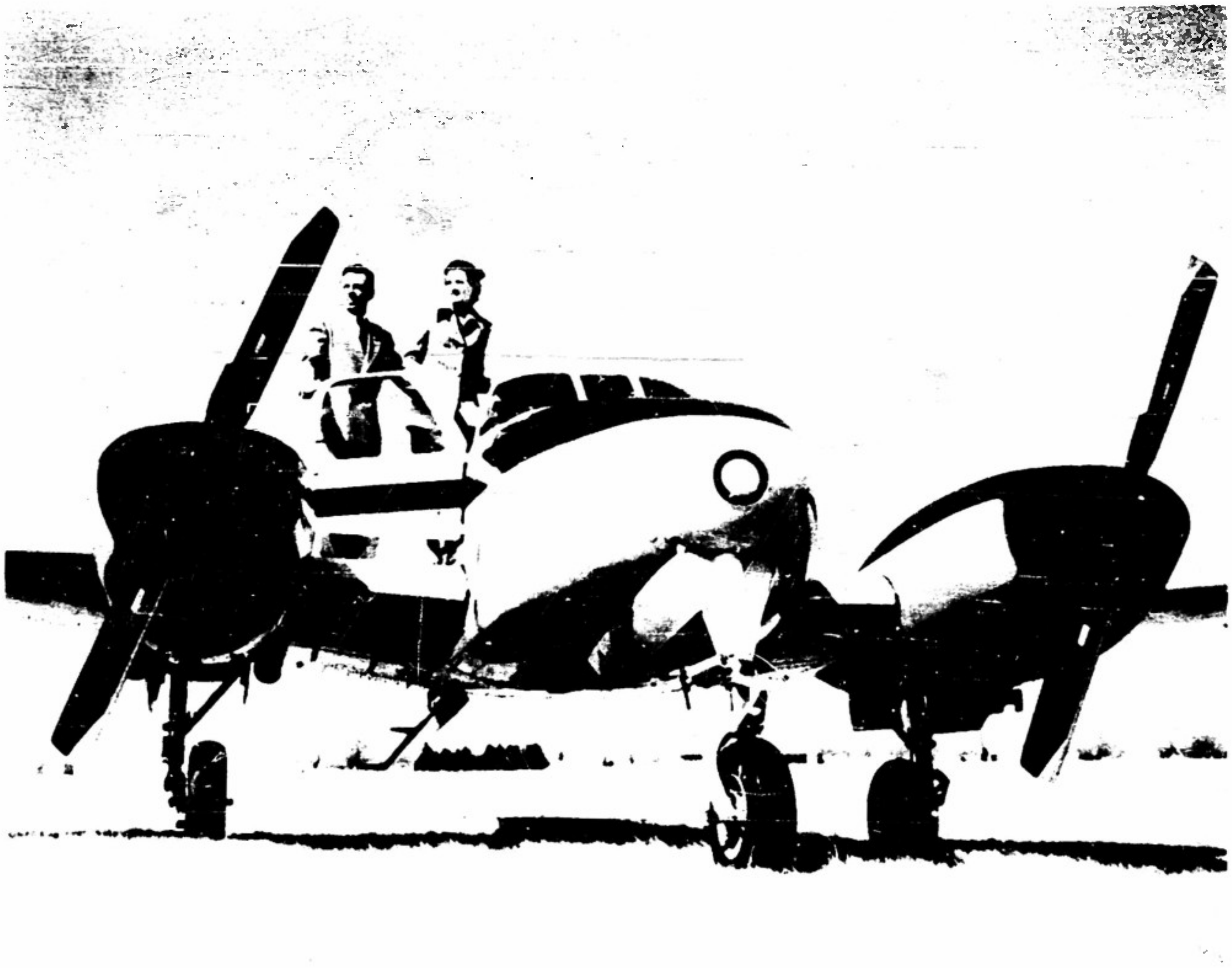


Figure: 8

The long nose (See Fig. 8) - with the engines far forward relative to the wing and cabin area - and the placement of the occupants above and aft of the leading edge of the wing provide a well developed "island of safety" to protect occupants in event of a crash landing.

The nine items listed below as well as the diagram of the Twin Bonanza are taken from Beech Aircraft Corporation advertising material and indicate that crash safety engineering can be used effectively as a sales point.

(1) "ENGINEERED for crash safety - with a reinforced cabin, long crash absorption nose and keel section, and over 62 percent of the weight below and forward of the occupants.

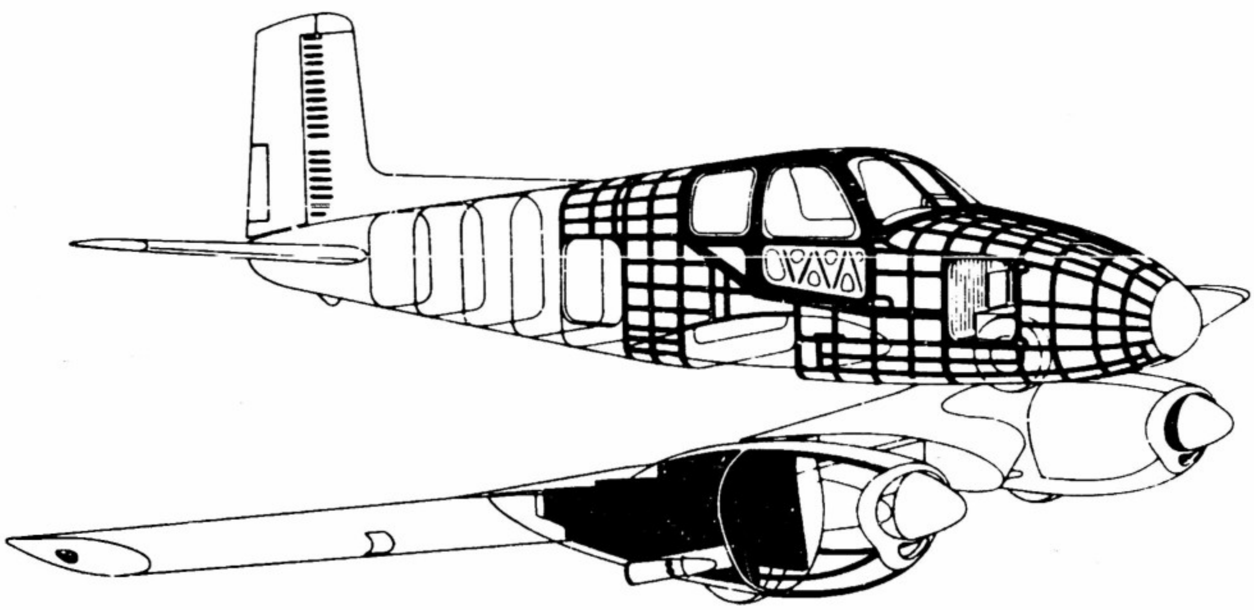


Figure: 9

(2) "MINIMUM WEIGHT AFT AND ABOVE CABIN. Only 4½% of gross weight is in a position to damage cabin in the event of a crash, compared to over 62% in high-wing airplanes.

(3) "STRONG, ENERGY ABSORBING NOSE SECTION serves as 'shock absorber' for the cabin section.

(4) "RUGGED DESIGN and construction - exceptionally high load factors assuring adequate crew safety and a long service life.

(5) "REINFORCED CABIN STRUCTURE to protect passengers from injury.

(6) "HEAVY REINFORCED KEELS and floor section protect occupants from below.

(7) "OVER 62% OF GROSS WEIGHT is placed below or forward of the cabin ... NOT ON TOP OF THE OCCUPANTS!

(8) "EXTRA STRENGTH. All the structure is tested to an 8g flight load factor, equal to carrying a 19-ton bridge, to provide the desired safety over and above the required load factors. Safety belt anchors are designed for 25g's. 25g safety belts or the 25g Beech safety harness are available for all occupants.

(9) (Listed under SPECIAL FEATURES, relative to the Instrument Panel): "a protective aluminum shield is provided to minimize injury in case of a crash."

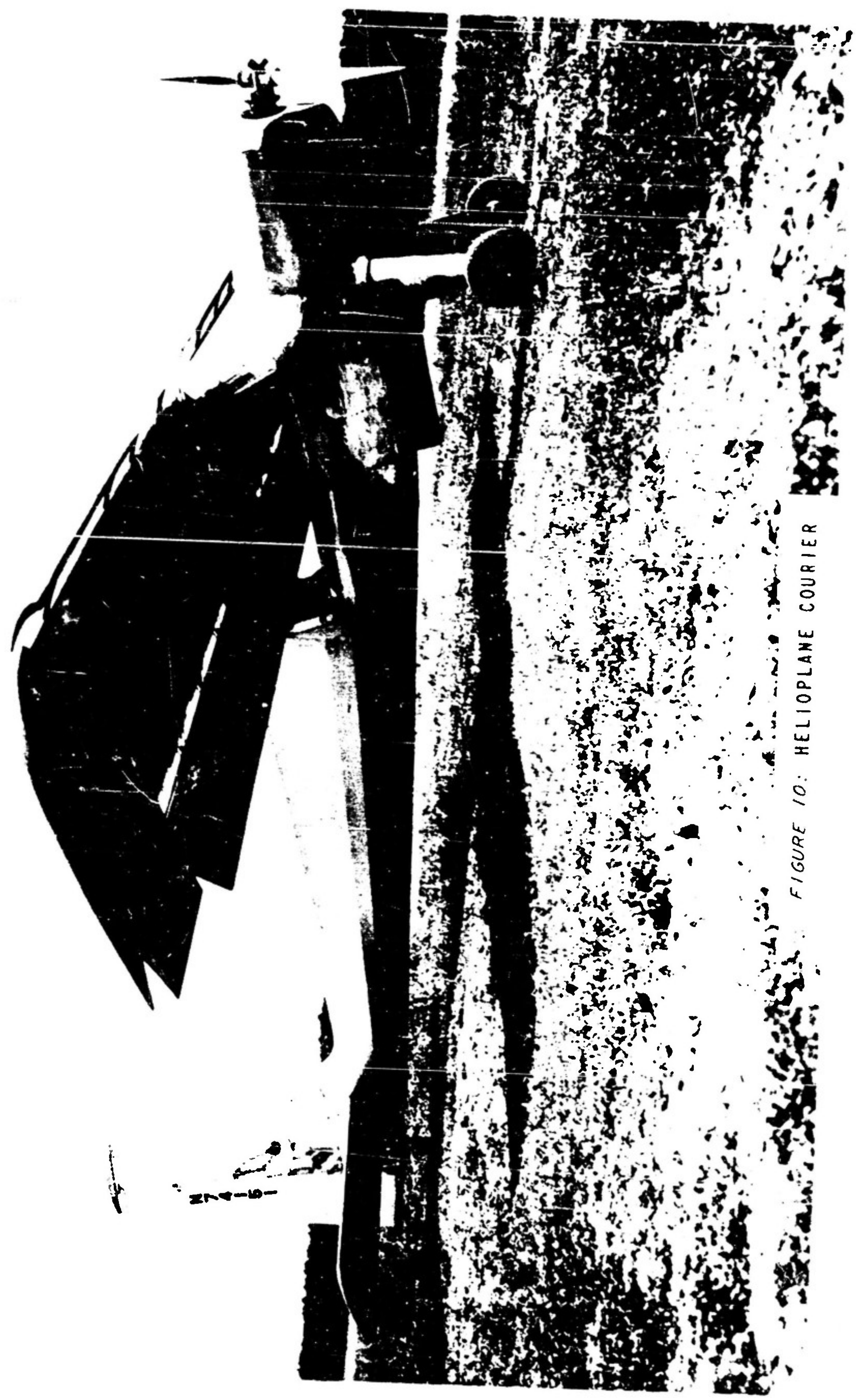


FIGURE 10: HELIOPLANE COURIER

HELIOPLANE COURIER

The Helioplane Courier is a single engine, 4-place all metal airplane with "semi-helicopter" performance and engineered protection for personnel in accidents.

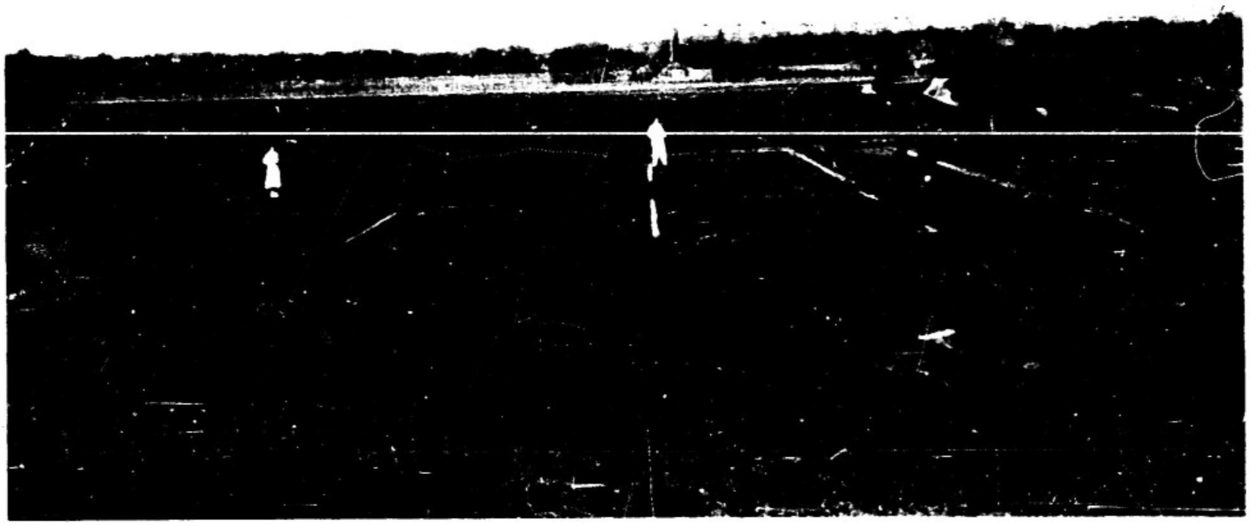


FIGURE 11

Utilizing various high lift devices, the Helioplane reportedly operates from a 300' strip (see Fig. 11), maintains level flight at 30 mph, and cruises at 140-150 mph.

In the words of company engineers the Helioplane is "designed to be the safest small airplane yet produced; the cabin structure is composed of welded tubing (see Fig. 12); the landing gear although conventional in appearance, is of rectangular cross section shape - to permit fore-and-aft flexing as well as vertical energy absorption. The landing gear legs are braced at a point approximately 6" below the longerons so that the gear will - in a crash - fail by progressive bending below this point, thereby absorbing energy without tearing open the bottom of the cabin" (see Fig. 13).

"A type of truss structure, designed to resist collapse during high g impacts, is utilized at crucial points in the cabin. For example, the tubing which forms a "V" just below the windshield is larger and stronger than will be found in many other comparable-sized planes"

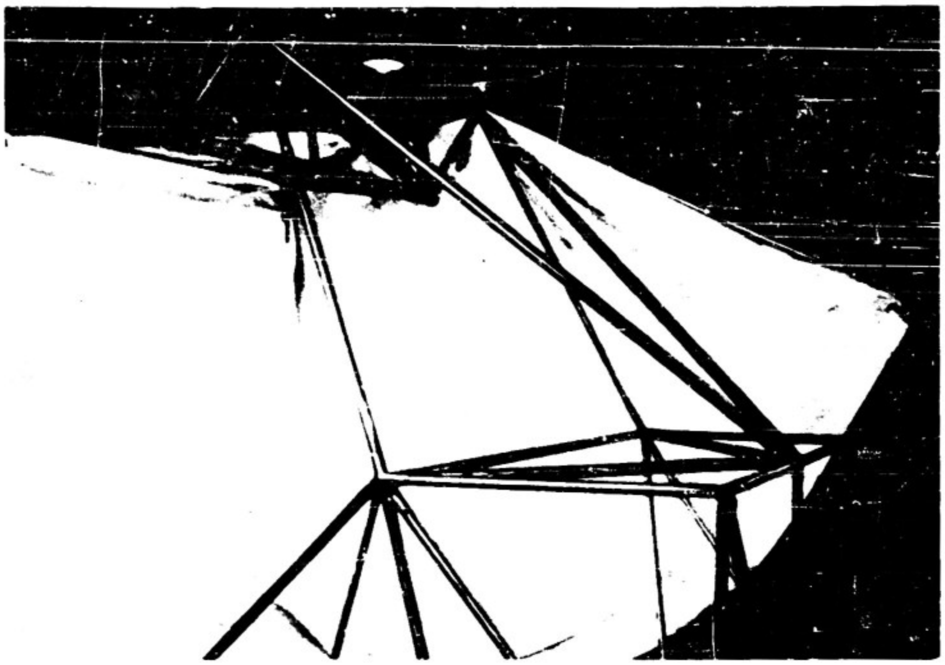


Figure 12: Despite the probable lower impact speed of accidents, special consideration has been given to reinforcing cabin structures. The over-size diagonal braces should check forward movement of the overhead wing attachment structure, as well as rearward movement of the engine into the cabin in crashes at minimum flight speed.

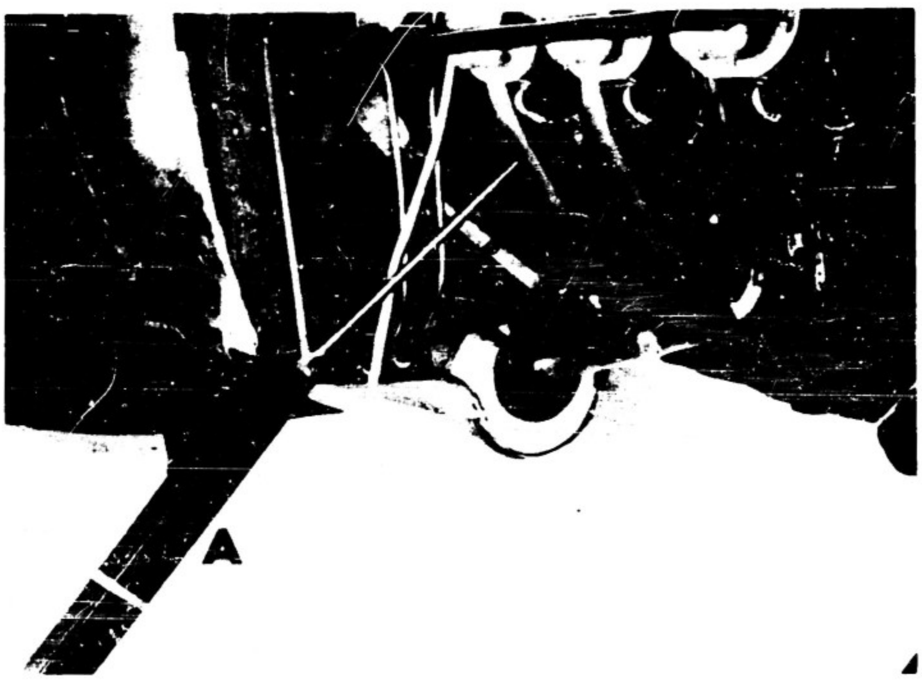


Figure 13: The legs of the landing gear are designed to flex and fail (at "A") outboard of the cabin; it is expected that this point of failure will increase the protection to the cabin and its occupants under loads which wash out the landing gear.

Figure 14: The floor structure, seat attachments, and the seats are stressed to resist a minimum of 15g deceleration loads without failure.

Figure 15: A combination safety belt and shoulder harness capable of resisting 4,275 pounds is provided as standard equipment for each occupant. Its "must-be-worn" feature should decrease the probability of injury in survivable accidents.

FIGURE 16: MEYERS "145"

MEYERS 145

The Meyers 145, a single engine 2-place executive-personal airplane with a conventional, retractable landing gear was designed with the two main objectives of (1) performance and (2) crash safety in mind.

Powered by a 145 horsepower engine, the Meyers "145" has a maximum speed of 166 mph and a sea level cruise of over 145 mph. Rate of climb is approximately 960 ft/min. Landing speed is 42 mph and safe minimum slow-flight velocity is under 50 mph.

The airplane has long nose sections which provide a large amount of energy absorbing structure ahead of the pilot and passenger. The long all-metal tail and wings also provide energy absorbing protection in cartwheeling accidents.

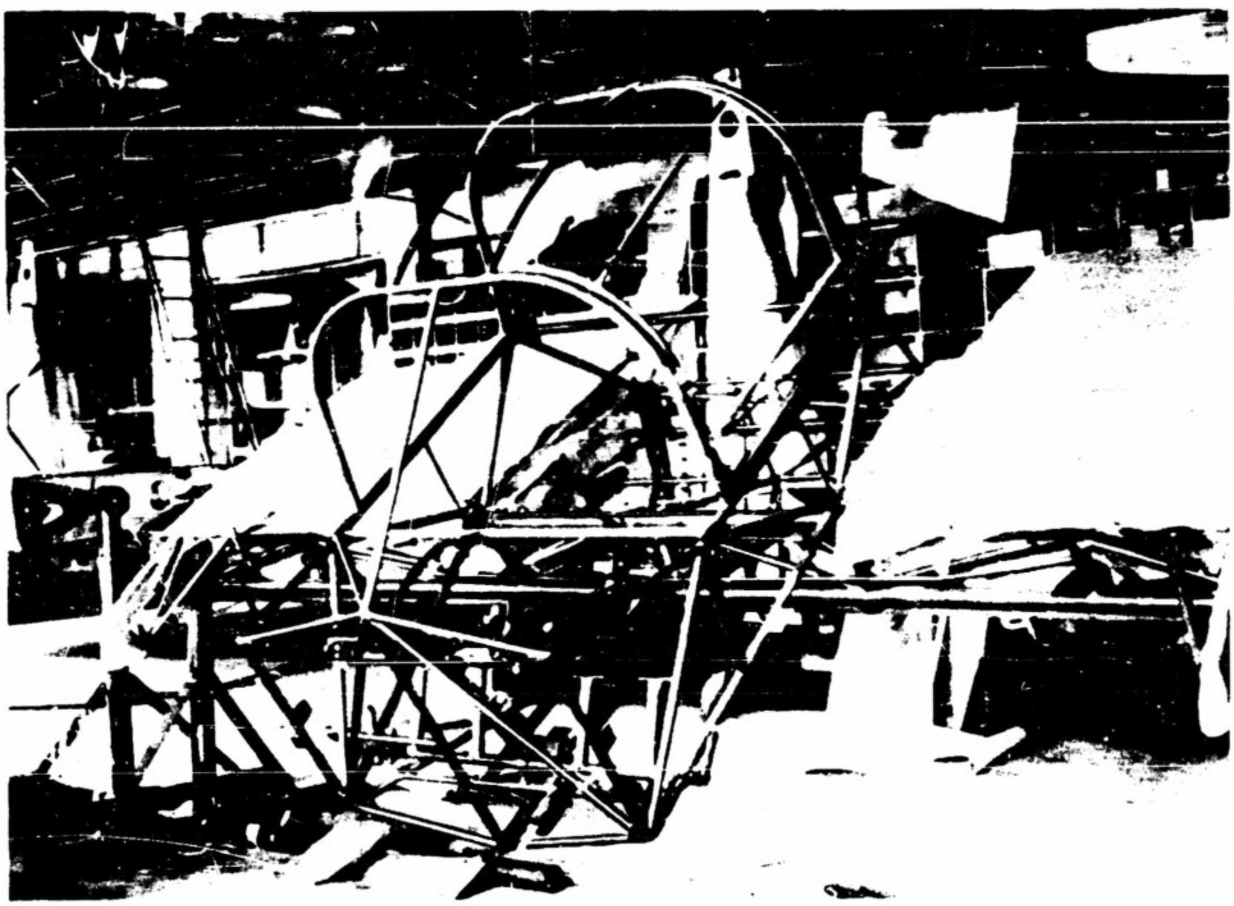


FIGURE 17

The cabin structure, as well as the center section, forward fire-wall area and the engine mount are all composed of large diameter welded steel tubes. (See Fig. 17) Since the aircraft was designed to withstand flight loads in excess of 7.5g, its resistance to structural collapse from impact should be greater than normally expected in this type of airplane.

Particularly noteworthy in the structural configuration of the cabin are the short bays and use of triangulation throughout which, in combination, produce a strong structure highly resistant to collapse regardless of direction of impact.

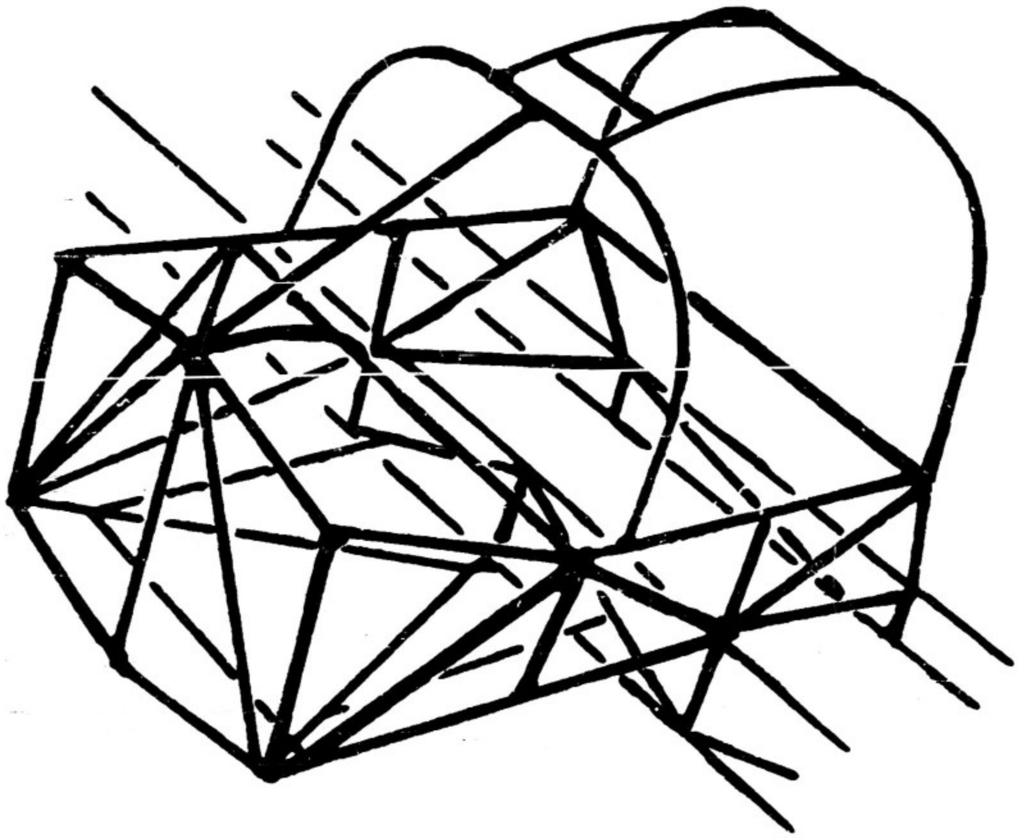


FIGURE 18

Steel tube rollover structure forms the cabin roof; the two top longitudinal members are curved outwardly to prevent inward kinking in the event of partial collapse of forward sections.

The bottom surfaces of the airplane present unobstructed passage to obstacles, in the event of a wheels-up crash landing; furthermore, the design of the engine mount and use of longitudinal tubes from the firewall to the bottom of the center section spar produces a "clean keel" which decreases the chances of the firewall "digging in" like a huge anchor, and thereby producing high decelerative forces in crack-ups.

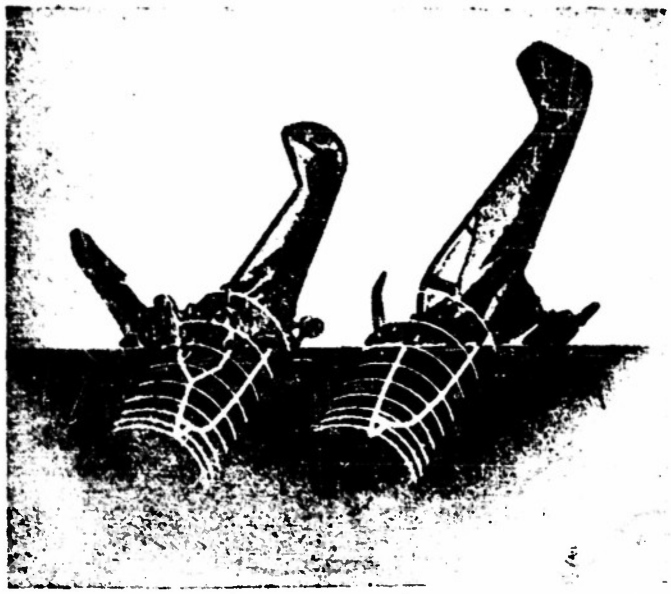
The landing gear is designed so that the upper oleo strut and attachment fitting will bend - and then fail without destroying the basic center section structure. This, of course, is also helpful in preventing post-crash fires.

A combination "must-be-worn" type safety belt and shoulder harness capable of resisting a load of 4,275 pounds, is provided as standard equipment for each seat. (See Fig. 19 and *Appendix 2*) The upper harness anchorage point is designed to resist a tension load of more than 1,500 pounds without failure. Customers have voiced approval of the harness, finding it both comfortable to wear and easy to put on and take off.

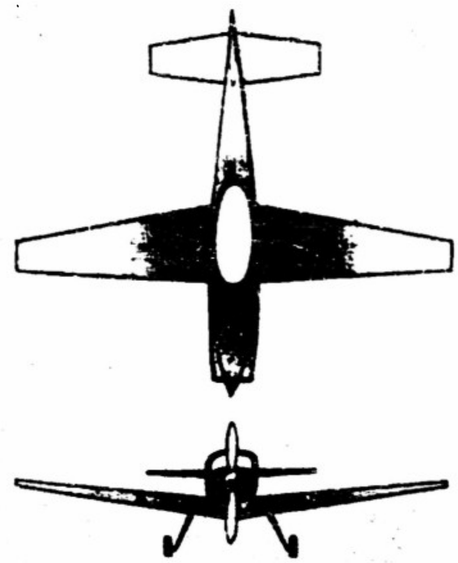
FIGURE 19

Use of crashworthy design in the cabin structure - plus the strong shoulder harness installations and the ability to maintain slow-flight speed - has produced an airplane in which it is virtually impossible to be seriously hurt in low angle, 30 to 50 mph crashes.

How Lightplanes Can Be Made Safer . . .



A Occupants' distance from nose of crashing plane may mean difference between life and death. Cockpit at right is intact.



B Cabin should be "citadel" of plane, with nose and wings designed to soak up force of crash, collapse away from the cabin.

Crash Safety *Can* Be Engineered

If today's lightplane incorporated all the safety features shown in the accompanying sketches, crash casualties would be drastically cut.

Released exclusively to AVIATION WEEK, these sketches illustrate many of the protective devices proposed by Cornell University's Crash Injury Research group—after eight years of thorough study of nearly 1000 lightplane accidents.

▶ **Body Rugged**—These safety features are based primarily on evidence that the human body, properly supported, can take crash impact forces better than any existing lightplane.

It already has been proven that persons, when supported, easily can withstand impact forces up to 35 Gs (AVIATION WEEK, Feb. 20). As for the human body's ability simply to survive crash forces, the indication is that this figure is near the bottom of the scale.

▶ **Make Plane Rugged**—But while a person harnessed in a seat can take it easily, a 35 G impact is more than conventional aircraft structures can withstand without destruction of the cockpit, so far as CIR can determine.

CIR believes private planes should have cockpit structures and body support provisions which can stand up to 25-35 G crashes at least as well as the persons in the plane. Give the occupants half a chance and "they'll walk away from most run-of-the-mill crashes." And more people will be interested in buying small planes.

Even if occupants are not properly supported and slam into cockpit structure in a crash, investigation points to the fact that chances of survival are raised considerably if there are fewer lethal objects, such as tubing, seat backs, instruments, etc., within range of the head.

Hugh De Haven, CIR director, stresses that injuries are "mechanical results" which largely can be controlled by aircraft design.

▶ **Lessening Danger**—Flight has brought with it the possibility of dangerous crash decelerations. But research now gives promise of taking a great deal of the sting out of accidents.

The course crash engineering is following logically leads to the day when occupants in private planes can expect to survive without dangerous injury when they crack-up at speeds up to 70-80 mph.—whether the plane hits vertically or at an angle, or smacks head-on into an obstacle. Even now, with virtually no crash protection, only about 10 percent of the persons annually involved in small plane accidents are fatally injured.

▶ **"Capsule" Safety**—It may not be too far in the future when occupants will be supported to exacting requirements in a structure which forms, in effect, a "protective capsule", carefully engineered not to collapse when the plane crashes into the ground up to a given speed.

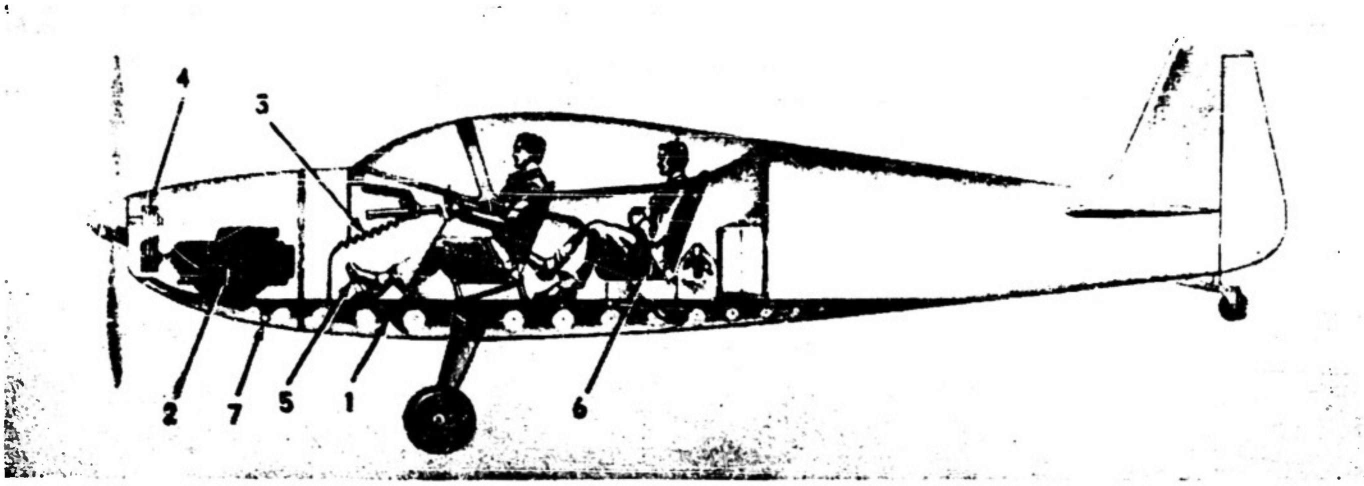
If the pilot, with this standard of protection built in his plane, is not exceeding this given "safe" flight speed in time of trouble, he can expect the structure around him to hold up, to stay in his seat, and to withstand the shock when the crash comes.

There now are planes in the design stage, providing protective features which, according to De Haven, "may assure pilots a greater degree of safety in the air than presently exists on the highways."

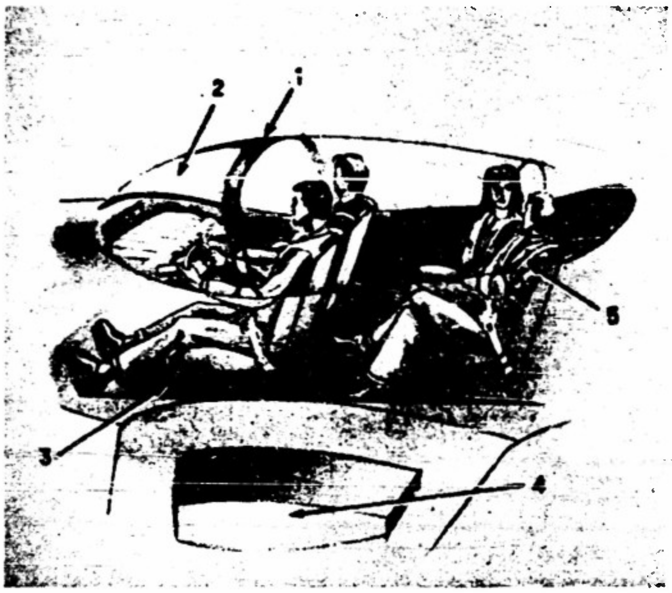
▶ **Proposals**—Keyed here to the accompanying illustrations are descriptions of major safety proposals made by CIR to increase crashworthiness and occupant survival in lightplane accidents:

A In plane, left, pilot sits close to nose with little crash-energy-absorbing structure and distance between him and engine. Arrangement is additionally dangerous by placement of gas tank between pilot and engine. Aside from fire hazard, pilot often is crushed when engine pushes gas tank and instrument panel into cockpit. Also, because of his forward position, he virtually "lands on his feet" in many crashes, with multiple injuries to lower extremeties.

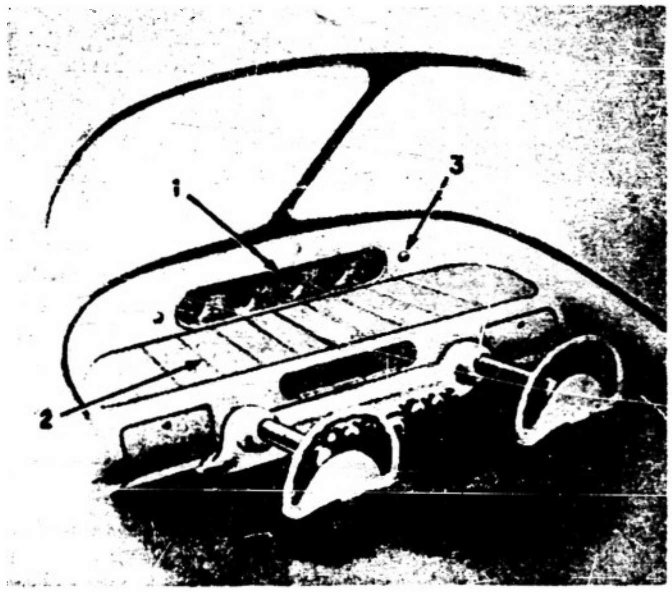
Plane, right, has structural arrangement now incorporated in several four-place craft. Pilot's seat is 7-10 ft. from nose, and tanks are placed in wing. By providing more structure between occupants and impact point, there is more opportunity for structural collapse and



C Safety features that can be incorporated: 1. Sturdy keel in case landing gear collapses. 2. Engine placed low for improved visibility. 3. Firewall backed by bulkhead. 4. Large propeller. 5. Strong rudder pedals. 6. Stronger safety belts. 7. Crash impact switch.



D All points in cabin and surrounding areas are designed to keep structure intact and protect occupants in a crash.



E Mounting instruments farther forward will guard against head injuries, cause of 75 percent of the fatalities.

greater absorption of crash energy ahead of cabin.

In line with this is CIR's finding that there should be "safer correlation between energy absorbing capacities of aircraft and minimum safe flights speeds." At present stage of aircraft engineering technique, "assured crash protection rapidly becomes impractical in small planes at speeds above 60 mph"

B Whether high-wing or low-wing configuration is used, cabin section should be strong point of the structure, and forward sections, wing panels and tail should be designed with decreasing structural strength away from cabin to give progressive collapse characteristics.

De Haven feels that if research were undertaken to analyze energy-absorbing properties of structures under kinetic loads, scientific data gathered in these experiments would allow major increases in crash protection with minimum weight penalties.

C Sturdy keel or skid (1) permits craft to slide instead of plowing into ground in low-angle accidents. In this type of crash, bottom edge of firewall in present aircraft often gouges into ground, causing extremely abrupt decelerations.

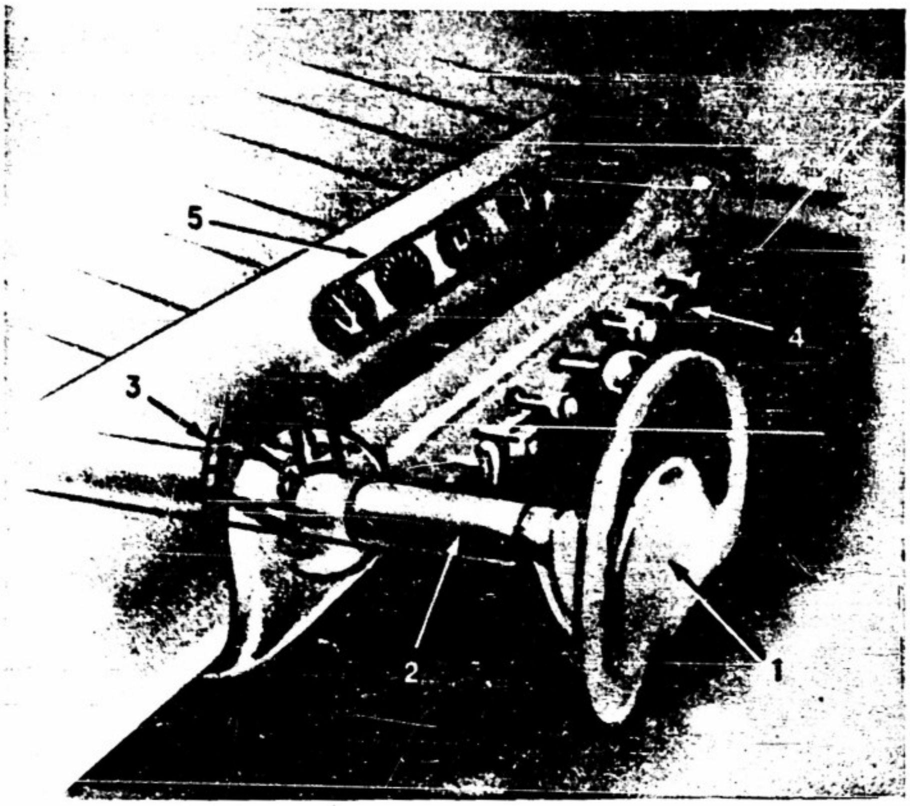
To prevent engine (2) from driving into cockpit, heavy firewall is backed by secondary, lightweight bulkhead (3). Air trapped between bulkheads provides "exceptional resistance to telescoping" of cockpit over engine section.

For greater forward visibility, even with pilot seated further aft, engine is lowered so that cowling can curve sharply downward from windshield, leaving only narrow cowling portion at center (indicated by shaded line). A larger propeller is suggested at a slightly higher position driven by gears or V-belt drive (4), to cut noise levels.

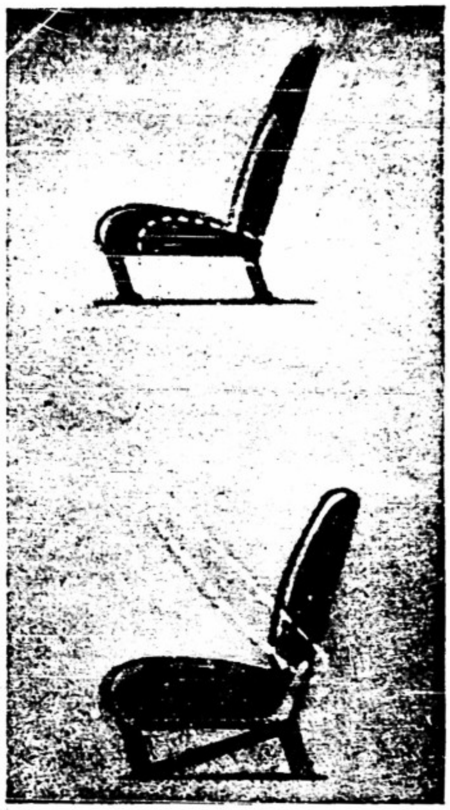
Rudder pedals (5) are designed to adequately support feet, while safety belts (6) have holding capacity of at least 25 G forward, 10 G upward, and 5 G to side. Belt loads should be carried to primary structure. If attached to seats, both structure and seat anchorage should be stressed to take equally heavy loads. An impact switch (7) cuts all circuits at battery when longitudinal deceleration is more than 6 G.

D Strong turnover structure is provided by T-shaped top brace (1). All bracing slopes away from passengers so there is less chance of direct head blows. Also, windshields and side windows (2) are designed to "pop out" instead of shatter if struck by occupants. Metal flooring or thin metal or fibre covering over plywood (3) lessens possibility that occupant's legs will be forced through cockpit bottom.

Fuel tanks are strong enough to withstand rupture in 20 G crash, are so



F **Control wheel and control column can be designed to support body when it is thrown forward, instead of being a spear to impale body.**



G **Front seats, though adjustable. should be firmly fastened to floor.**

placed as to make it difficult for them to be crushed or punctured in survivable accidents.

If wing tanks (4) are employed, De Haven suggests constructing them with slightly weaker outboard ends so that if they burst in a crash, "the gasoline normally will be sprayed away from engine, cabin and occupants," thus lessening the danger.

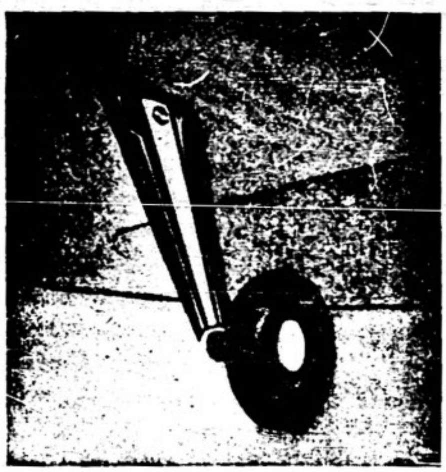
CIR is a strong advocate of shoulder harness (5), pointing out that if it were used faithfully "it would not be necessary to modify, rearrange, and redesign structures specifically to protect the head. However, no modern personal aircraft has shoulder harness as standard equipment and experience has shown that few pilots understand its value . . ." Hence, it is important to design cabin so as to minimize injuries resulting from headblows, which are sure to come in crash when occupants refuse to take advantage of shoulder harness.

E Considering that 75 percent of fatalities in survivable lightplane accidents are caused by head injuries, heavy flight instruments (1) are mounted well forward out of head range, but closer to pilot's line of vision. If he jacknifes over seat belt in crash, he hits "flight deck" (2), a soft metal shelf designed to absorb head impact. De Haven points out that, while skull fracture can occur if the head strikes an unyielding object at an impact velocity of 12 mph., injury may be avoided at 50-60 mph if the head hits a ductile object which can "give" approximately 5 or 6 in.

Still more protection is given by mounting instruments on separate panel secured to cockpit cowling by shear grommets (3) or inertia latches. In crash decelerations exceeding 6 G, instruments are thrown forward, out of range of pilot's head.

F Control wheel (1) distributes crash force over large area of chest and provides, as nearly as possible, protection equivalent to that given by shoulder harness. It is made of metal which will bend, rather than break, under heavy loads, and is attached to permit yielding, and adjustment to chest loads. Control column (2) is strong enough to resist buckling under heavy, forward and side loads and is equipped with inertia locks (3) which check rapid forward movement of column in decelerations of more than 6 G. Control knobs (4) are of soft material to prevent injury and each is shaped differently so that it may be identified by touch as well as by position. Small gages (5) also can be mounted to tear loose from panel.

G Front seats are adjustable, yet firmly anchored to prevent loosening under safety belt loads. They are capable of supporting 20 G compression loads without breaking. Where no shoulder harness is used, backrests on front seats are hinged to swing forward, out of head range of occupants in the rear seats.



H **Even landing gears can be designed to absorb energy before force hits structure.**

H Spring type landing gear is tapered to give increasing resistance when loaded vertically. In addition, it is attached to fuselage by friction joint for pivoting aft when loading would cause normal landing gear or structural attachments to fail. In low-angle crashes this arrangement would permit more crash energy to be absorbed since it permits a greater distance of deceleration and lower G-loads imposed on the aircraft proper.

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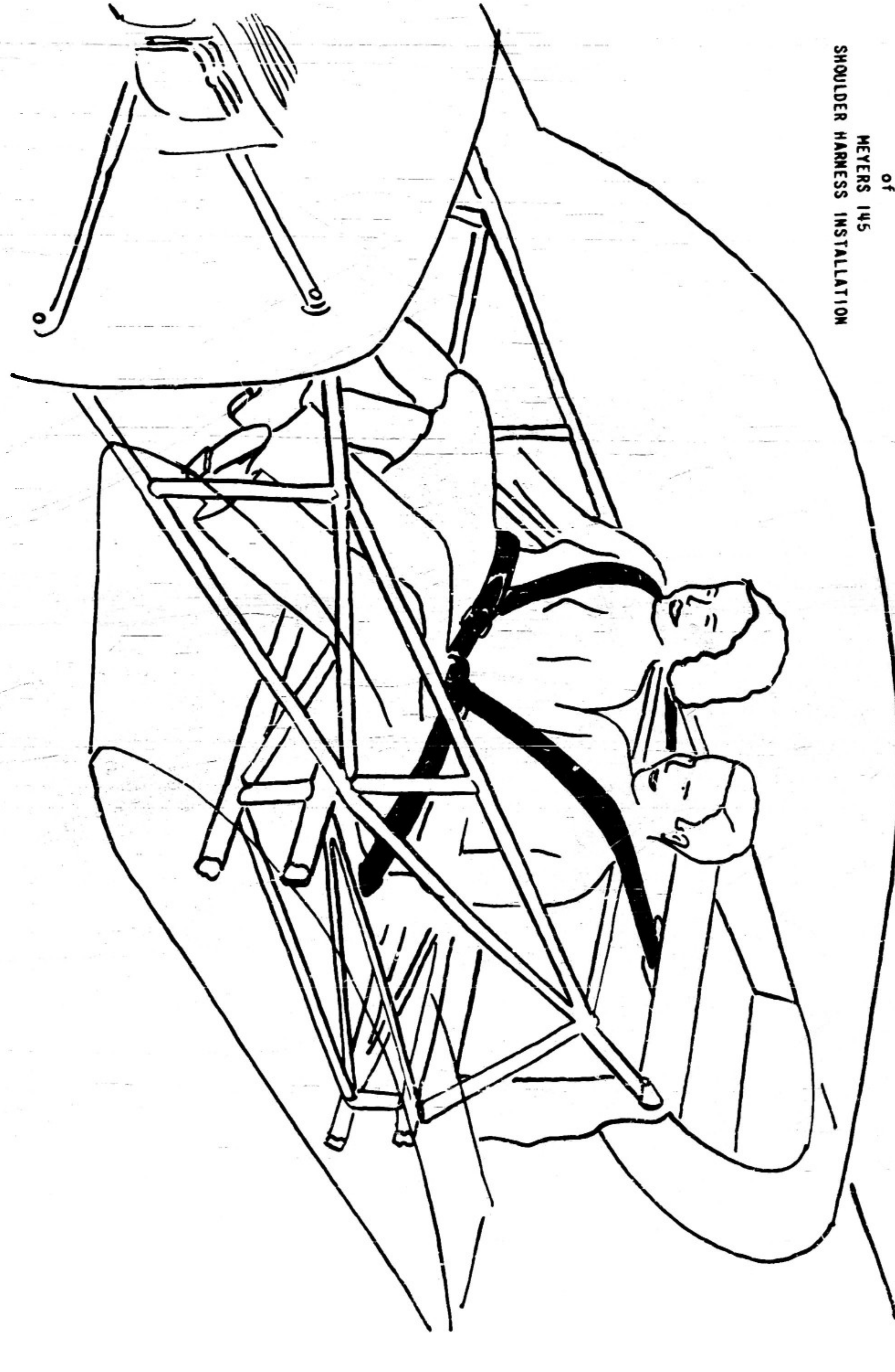
APPENDIX 2



SCHEMATIC DIAGRAM
of
MEYERS 145
SHOULDER HARNESS INSTALLATION